FEM structural analysis and optimization of a drift chamber made in composite materials.

Istituto Nazionale di Fisica Nucleare

Lecce unit

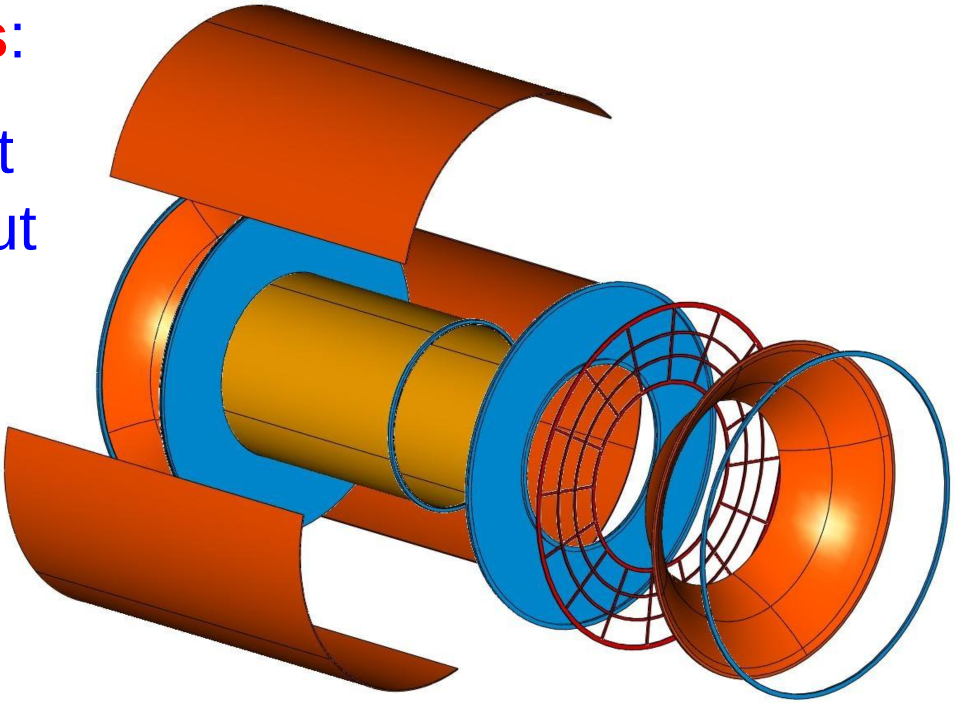
Mesagne unit

Design of the I-tracker

End-plates

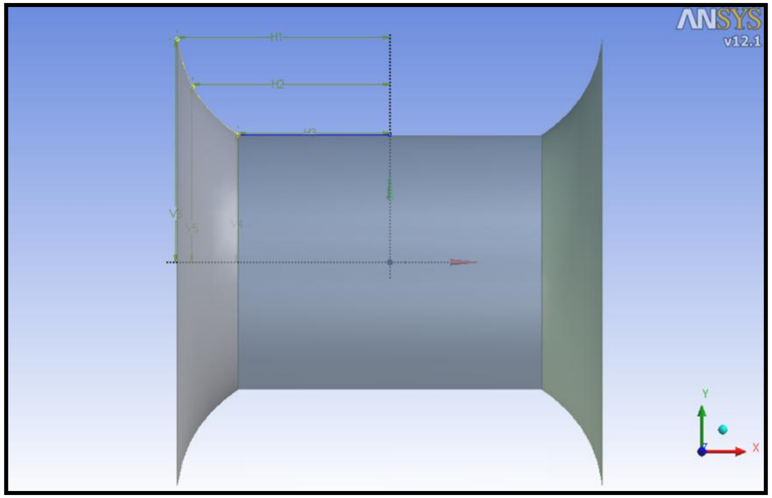
Separate the **wire holding** function from **gas tightness**:

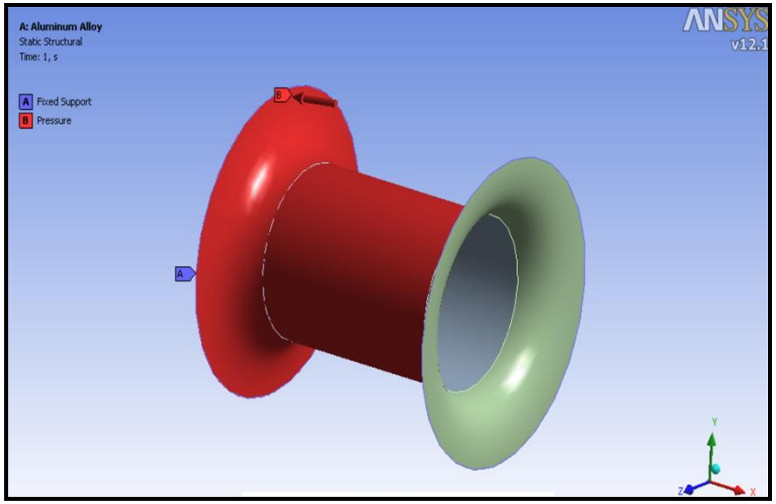
- wire holding structure must be **undeformable**, but not necessarily **gas tight**
- gas envelope must **withstand pressure** but is free to sustain large **deformations**



The structure of the Drift Chamber

The CAD model, loads and constraints





The structure of the Drift Chamber is composed by:

- Two external end plates
- An internal cylinder

The geometric constraints are:

- Cylinder length
- Internal cylinder radius
- External cylinder radius

The structural boundary conditions are:

- External pressure normal to all surfaces
- Fixed supports on the outer edge of the plates

What were the unknowns of the project in the first phase?

Geometrical optimization

The best profile of the end plates.

- **Minimum value for the maximum eq. stress**
- **Minimization of stresses and displacements in the contact regions (cylinder / plates)**
- **Minimize the maximum value of the IRF**

Mechanical behavior

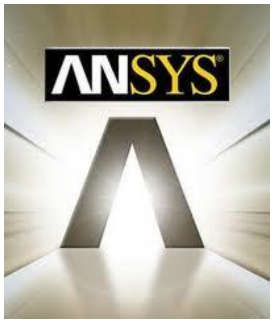
Structural response of the drift chamber using an isotropic material.

Material choice

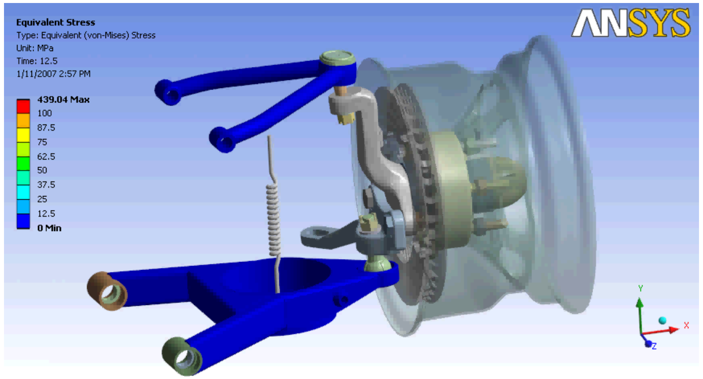
Investigation about the best composite materials in order to satisfy the goals.

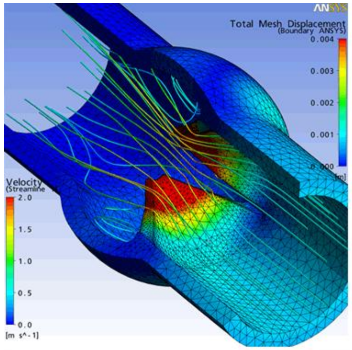
Industrial feasibility

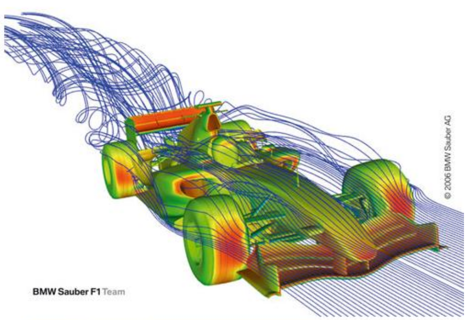
Verify the feasibility of the structure, monitoring costs and quality too.

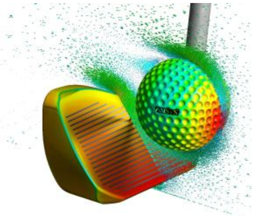


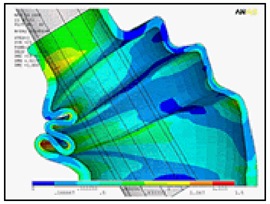
ANSYS provides a comprehensive coupled physics tool combining structural, thermal, CFD, acoustic and electromagnetic simulation capabilities in a single software product.

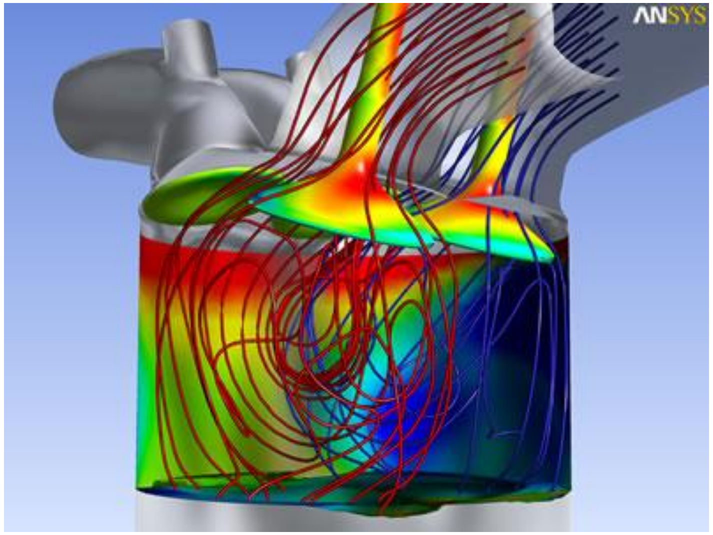


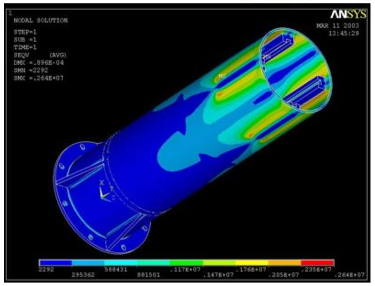


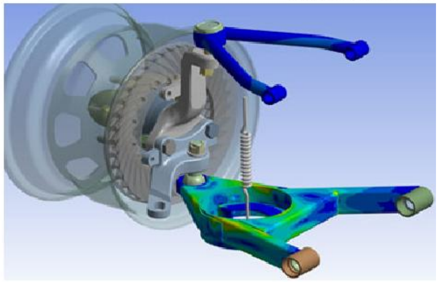


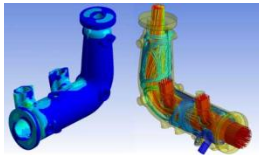










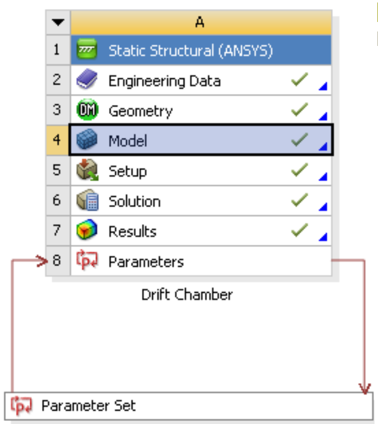


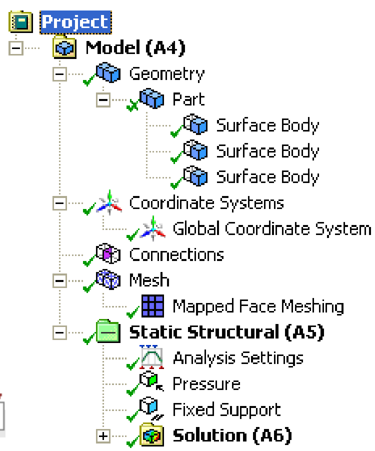
ANSYS WB - Mechanical Simulation

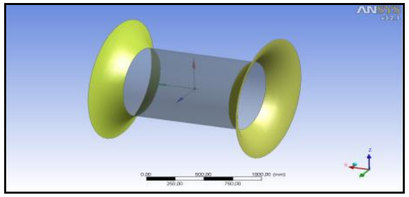
Static Structural

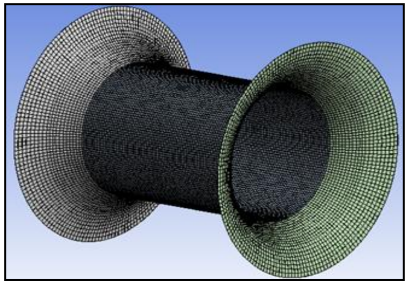
A very complete and user-friendly interface allow us to …

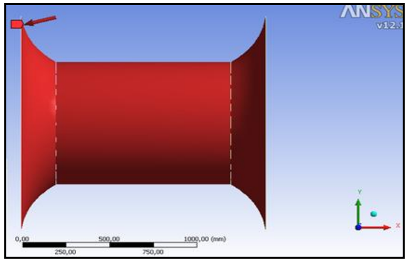
- choose the materials
- model the structure as parametric geometry
- mesh the geometry
- set the boundary conditions
- solve the structural problem
- analyze the results
- parameterize each physical quantity

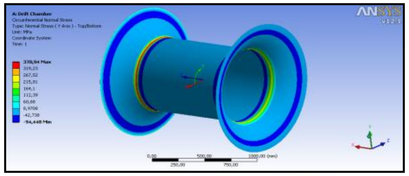








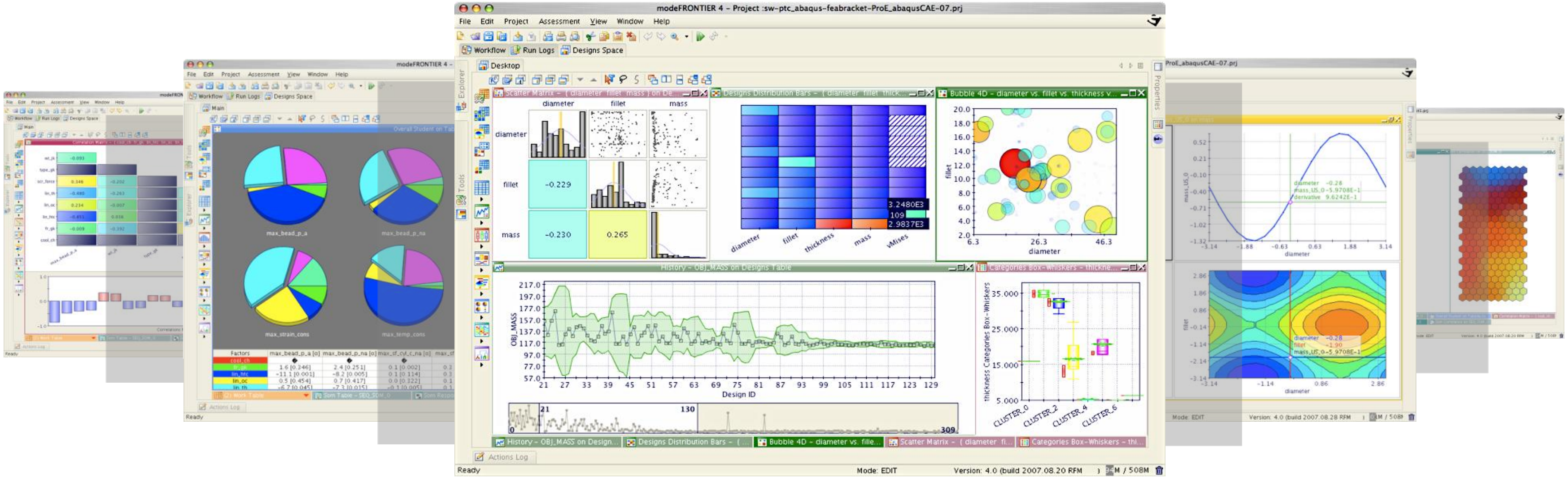




Really, the results obtained after the simulation of the structure in its first attempt configuration, don't ensure the best behavior of the Drift Chamber. So, we can link the structural analysis made by ANSYS WB with a multiobjective optimization environment: modeFRONTIER.

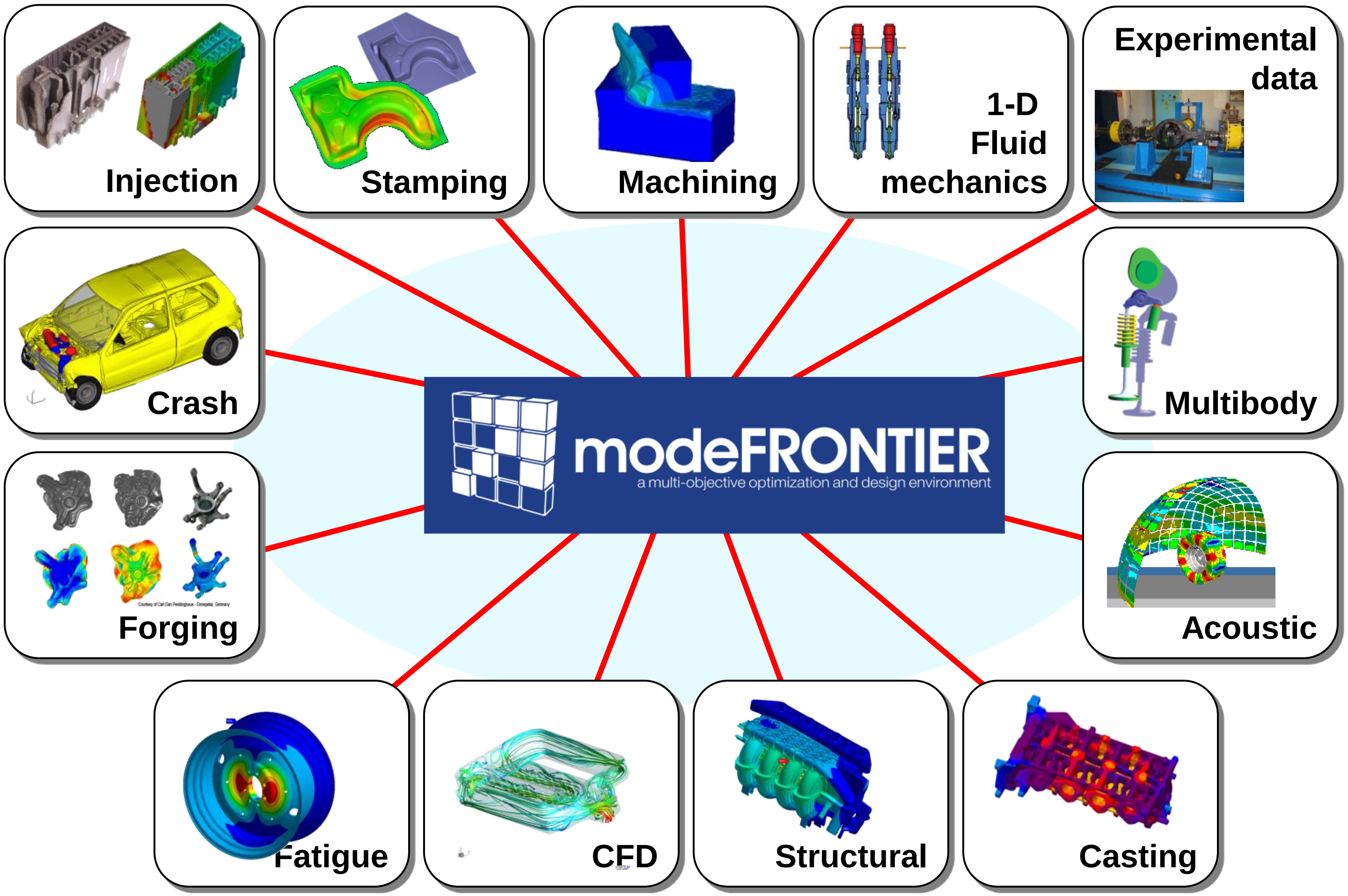
ENGIN SOFT

modeFRONTIER
a multi-objective optimization and design environment



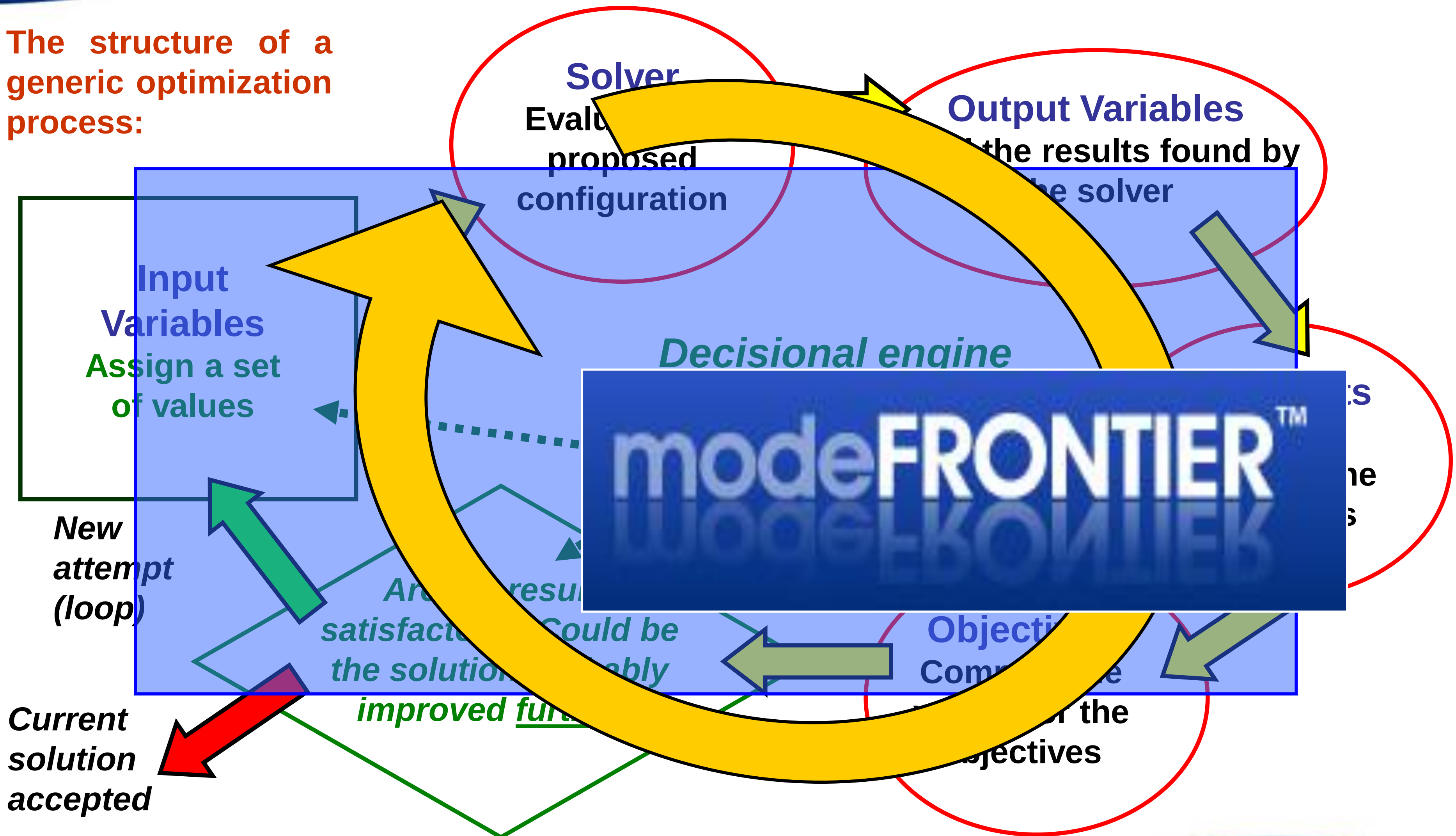
modeFRONTIER is a multi-objective optimization and design environment, written to allow easy coupling to almost any computer aided engineering (CAE) tool, whether commercial or in-house, and to perform advanced data mining

Why EnginSoft? Multidisciplinary



Optimization Concept: logic flow – the “brain”

The structure of a generic optimization process:

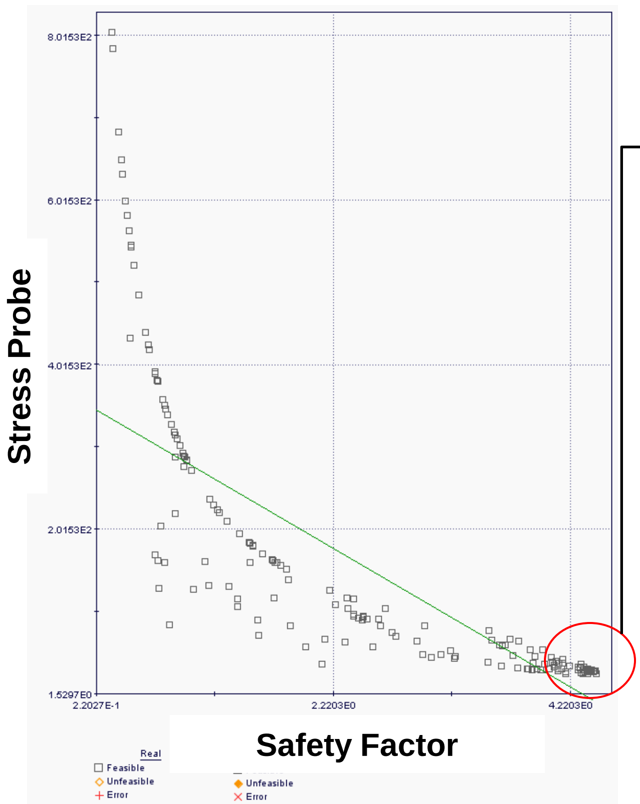


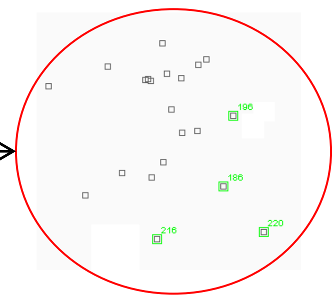
Geometrical optimization of the chamber' shape changing the coordinates of the three points of the spline.

ModeFRONTIER workflow for the geometrical optimization

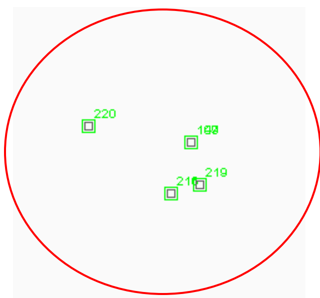
- **Input data**
  - H_central
  - V_central
  - H_end
- **DOE – Design of Experiments**
- **Optimization strategy**
  - Genetic algorithm MOGA-II
- **Solver node**
  - ANSYS WB project
- **Objectives**
  - Minimize max stress
  - Minimize stress on the contact regions
  - Maximize Safety Factor

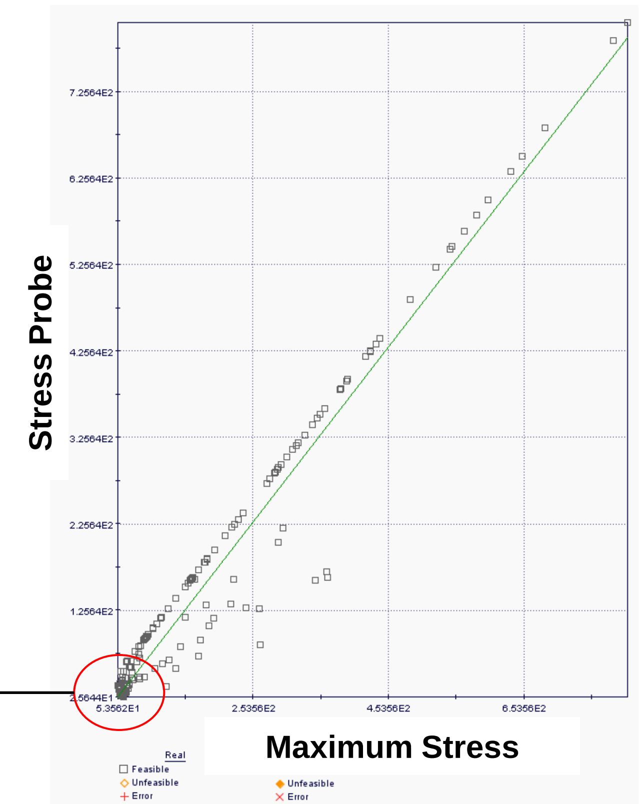
The results of the modeFRONTIER multiobjective optimization





Pareto frontier

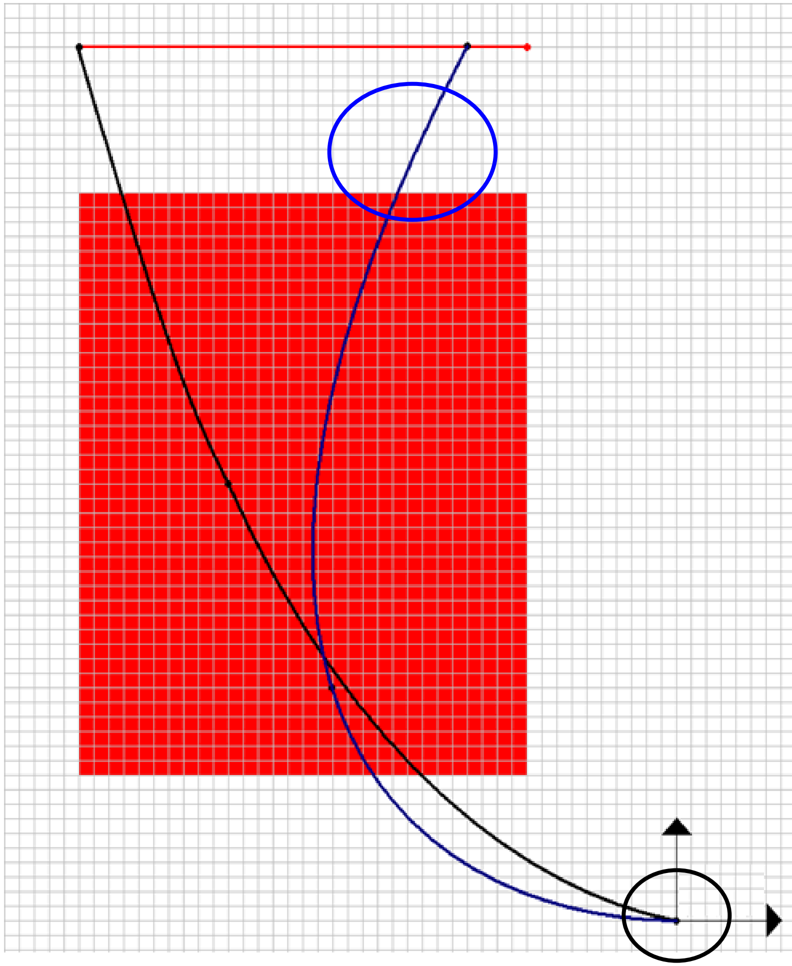




In these graphs is shown the trend followed by the designs built in ModeFRONTIER.

We can see that the genetic algorithm drives the designs towards the optimal zone.

The new end plates shape – geometrical optimization



The best configurations are 4, and their coordinates are all close.

On the left we can see the new profile of two symmetrical end plates.

First attempt configuration

Optimized design by modeFRONTIER

Note: in the structural analysis with the first attempt configuration, the minimum safety factor was about 0,8 (failure conditions), and the most critical zone was corresponding to the contacts between cylinder and plates.

In the best configuration the SF is equal to 4,44 and the most critical zones are near to external constraints

ESAComp

The choice of the custom composite materials

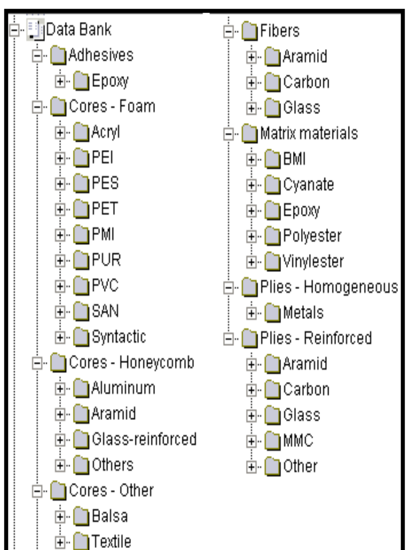
ESAComp is the software used to design and analyze the composite laminates.

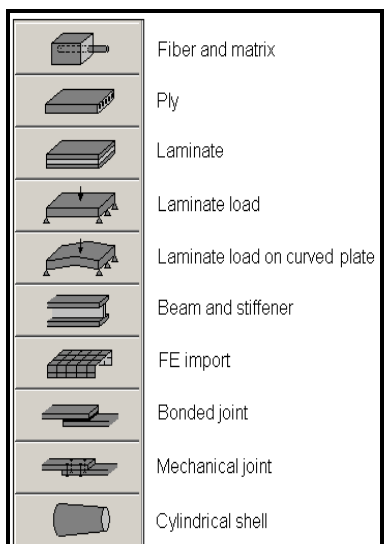
It's possible to find the best composite materials in a big database and to create a custom material

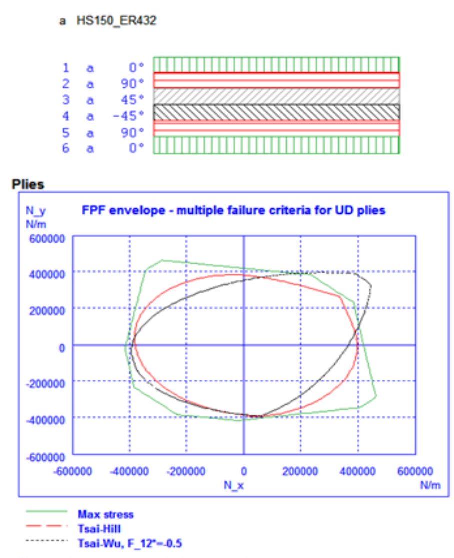
We can create a custom ply or laminate and bring forward some kinds of analysis

ESAComp allows to analyze the laminates through the Classical Lamination Theory

Other tools and applications are available in ESAComp, including:







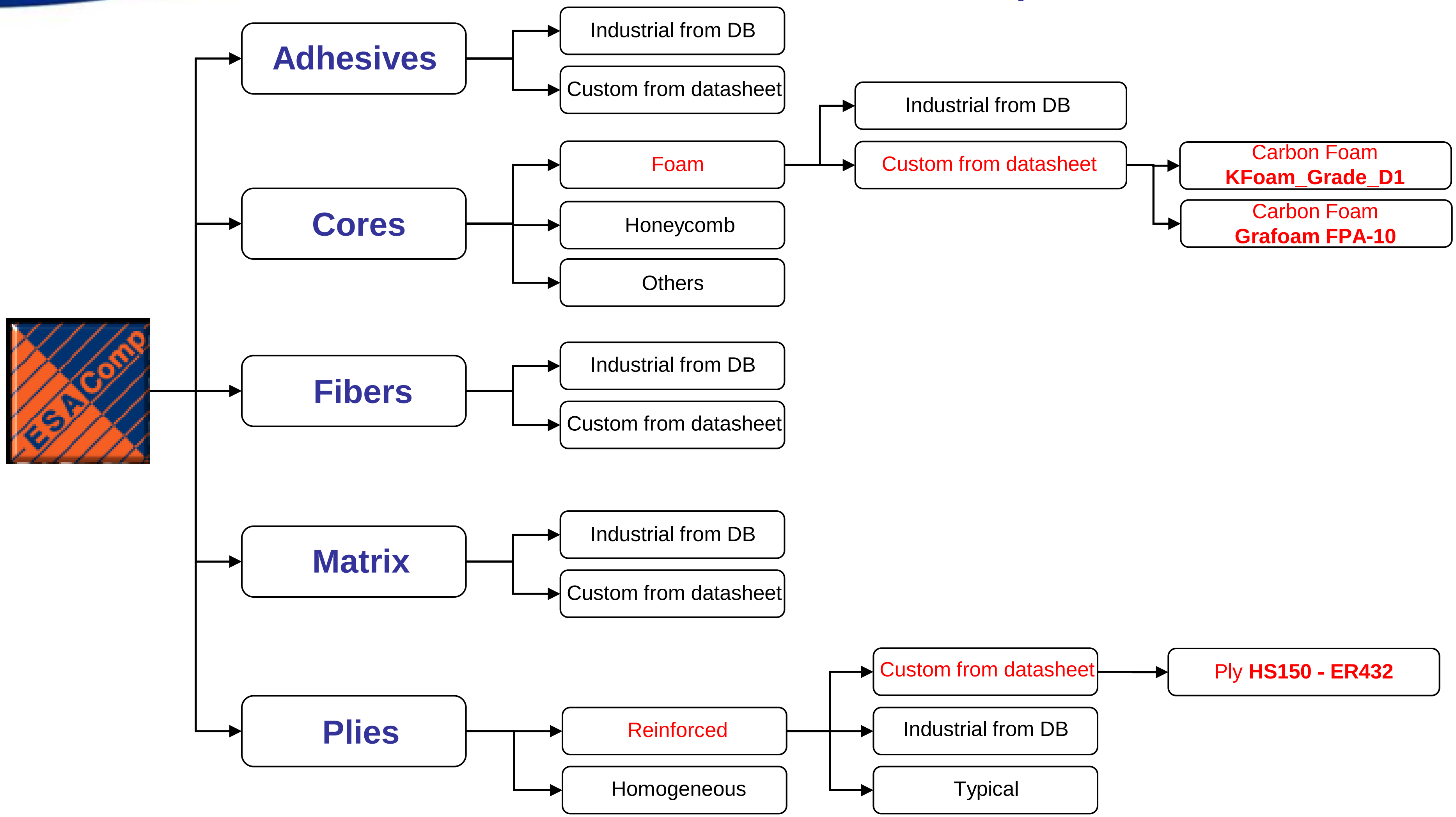
Robust design

Costs analysis

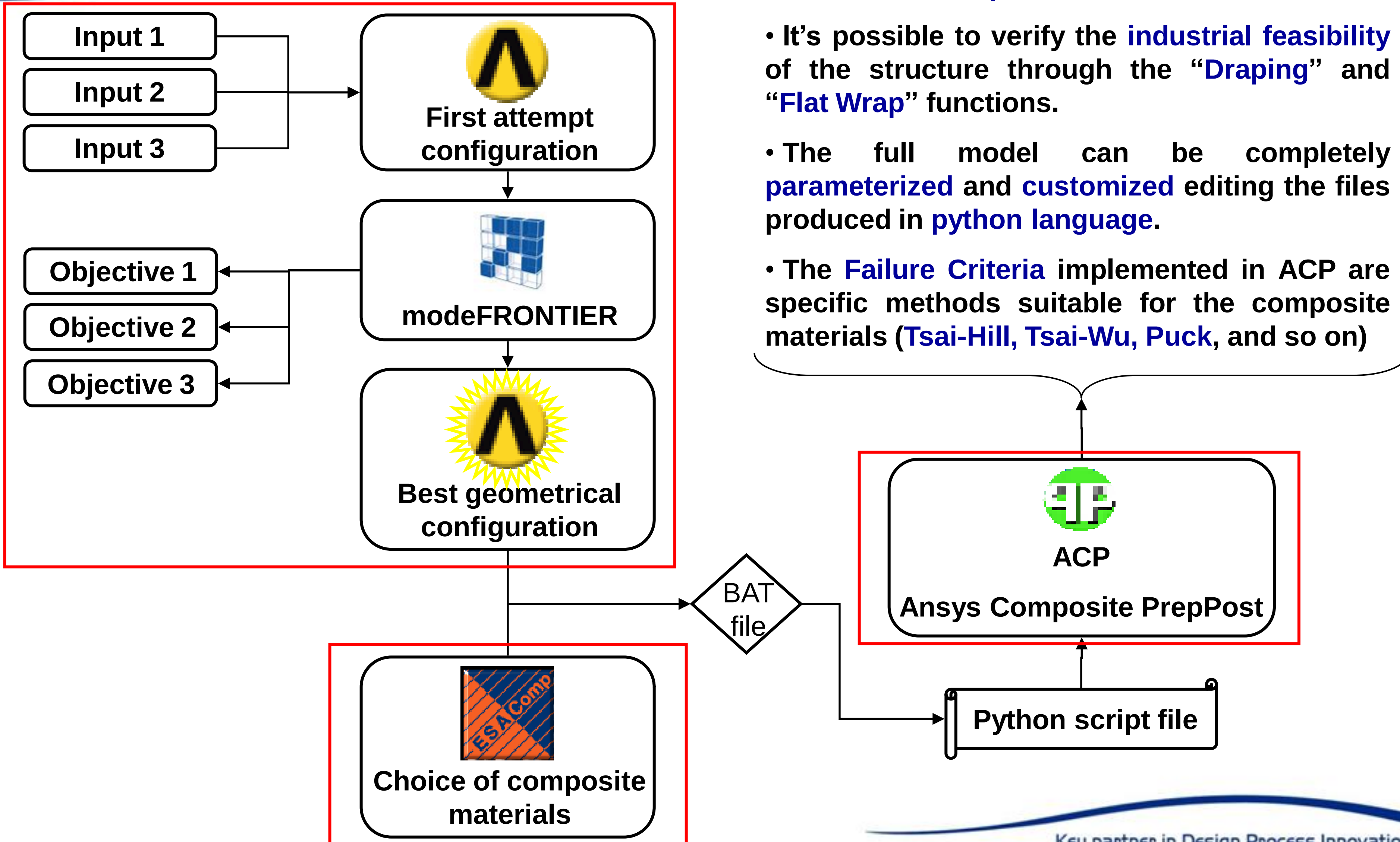
Thermal analysis

Hygrometric analysis

The choice of the custom composite materials



- With ACP we can verify the structural response of the model using the **WB model** and the **ESAComp materials** chosen.
- It's possible to verify the **industrial feasibility** of the structure through the "**Draping**" and "**Flat Wrap**" functions.
- The full model can be completely **parameterized** and **customized** editing the files produced in **python language**.
- The **Failure Criteria** implemented in ACP are specific methods suitable for the composite materials (**Tsai-Hill, Tsai-Wu, Puck**, and so on)



ACP – Ansys Composite PrepPost

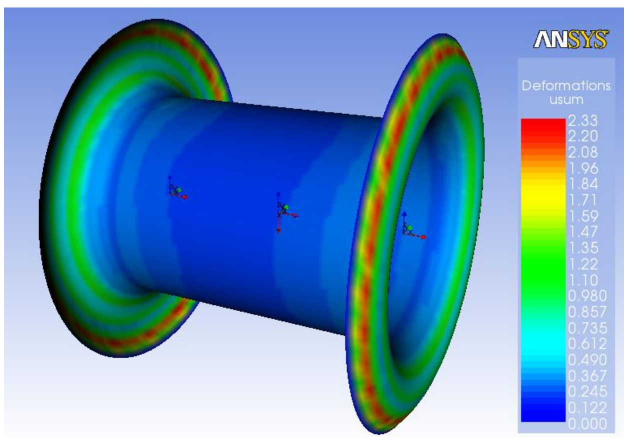
→Import the model from ANSYS WB

→Read the properties of the composite materials and associates these to the model

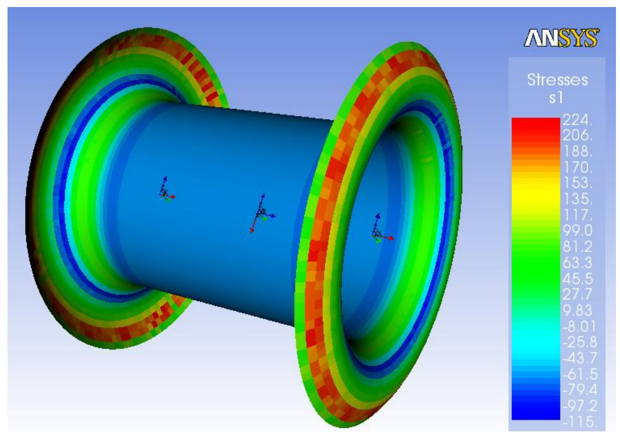
→Verify the feasibility through the draping function

→Solve the static structural analysis

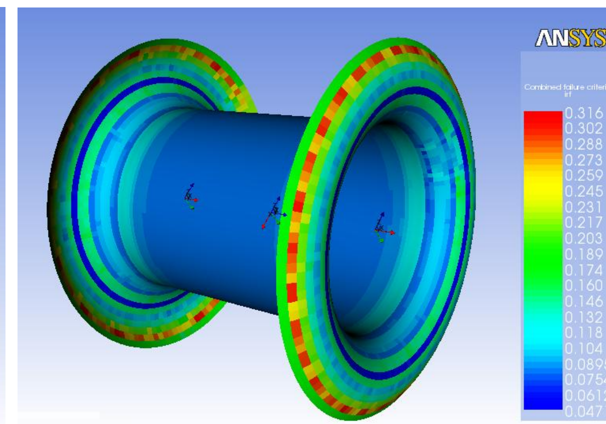
→Read the results and analyze the response with composite Failure Criteria.



Displacements sum



Stress contours



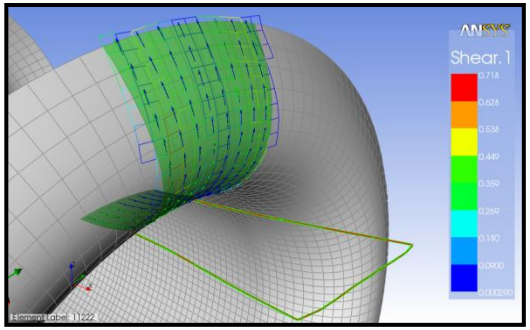
Inverse Reserve Factor

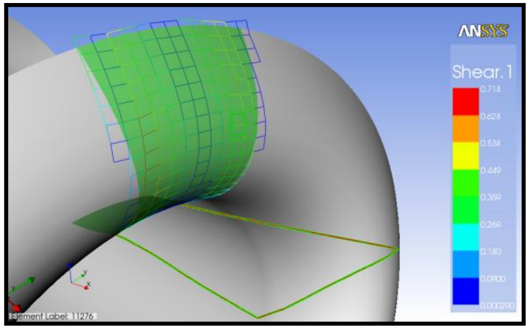
RESULTS

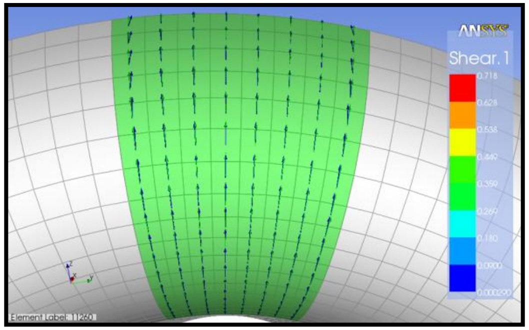
Draping of the ply and Flat-Wrap

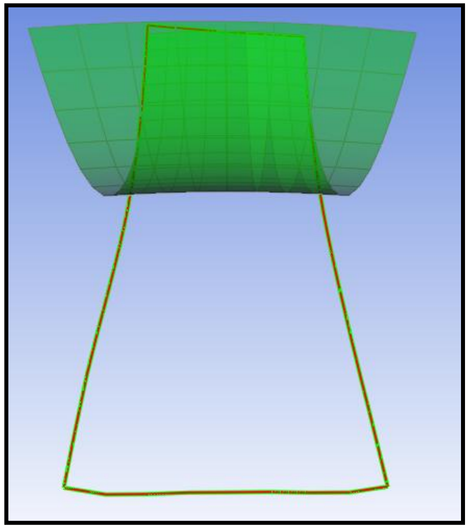
FEA Developments in ACP - Feasibility of the geometry

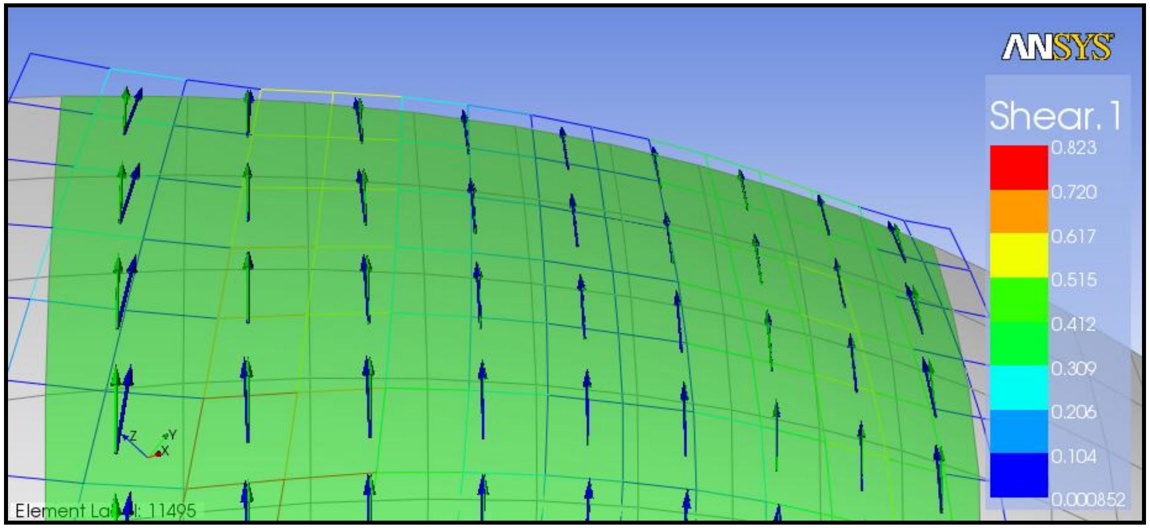
Geometric analysis of the end plates and convergence solution in ACP, draping of laminates and Flat-Wrap of the model, static structural analysis in ACP for different configurations (4 laminates created with the unidirectional prepreg chosen).









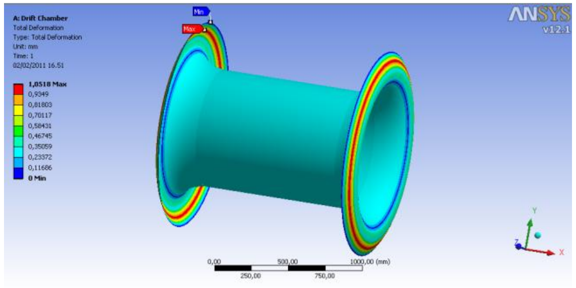


BUCKLING INSTABILITY

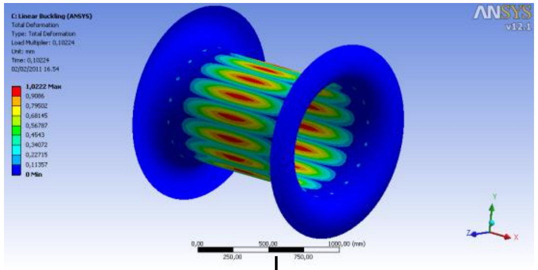
The static structural analysis isn't enough to ensure the positive response of the Drift Chamber, because the load imposed causes the buckling mode.

Complete analysis

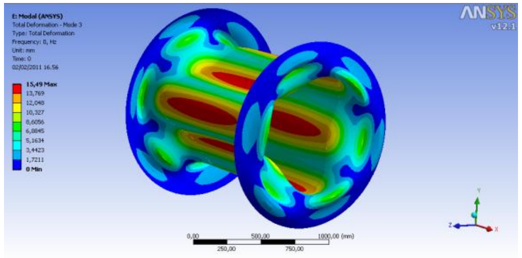
Static structural



Linear Buckling



Modal



The structure of the Drift Chamber was in failure conditions due to buckling instability.

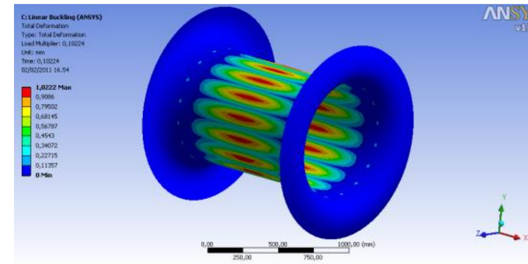
The critical behavior is focused in the midsection of the cylinder.

WB - Static Structural + Linear Buckling (with Aluminum alloy)

Aluminum

LOAD MULTIPLIER

$$\lambda = \frac{\text{Critical buckling load}}{\text{Current load}}$$



ACP - Static Structural + Linear Buckling (composite materials)

Choice of core materials (ESAComp)

KFoam_Grade_D1

Grafoam FPA-10

The best ACP Static Structural model of the Drift Chamber

Composite Materials

LOAD MULTIPLIER

$$\lambda = \frac{\text{Critical buckling load}}{\text{Current load}}$$

To ensure a good structural response, the load multiplier must be greater then 1.

We have simulated in ACP about 40 different configurations, changing the lay-up of the cylinder and the thickness of the cores.

The results obtained for the acceptable designs are shown below

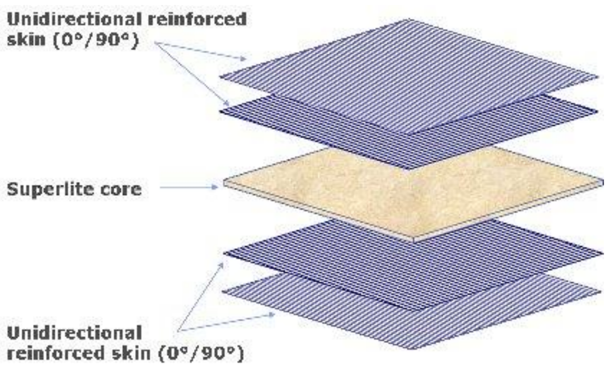
Kfoam_Grade_D1

	Lay-up piatti esterni	Lay-up del cilindro	Numero ply	Spessore ply	Spessore CORE	Spessore totale del cilindro [mm]	m_A ply [g/cm2]	m_A core [g/cm2]	m_A cilindro [g/cm2]	Load Multiplier	Massa cilindro [kg]	Massa piatti [kg]	Massa totale [kg]
19	0-90-90-0	0-90-CORE-90-0	4	0,153	5,388	6	0,0211752	0,258624	0,3433248	1,015331	8,627878776	2,219160351	10,84703913
20	0-90-90-0	0-90-CORE-90-0	4	0,153	6,388	7	0,0211752	0,306624	0,3913248	1,322407	9,83413647	2,219160351	12,05329682
31	0-90-90-0	90-0-90-CORE-90-0-90	6	0,153	4,082	5	0,0211752	0,195936	0,3229872	1,252976	8,116787392	2,219160351	10,33594774
32	0-90-90-0	90-0-90-CORE-90-0-90	6	0,153	5,082	6	0,0211752	0,243936	0,3709872	1,634037	9,323045085	2,219160351	11,54220544
36	0-90-90-0	0-90-90-0-CORE-0-90-90-0	8	0,153	3,776	5	0,0211752	0,181248	0,3506496	1,278087	8,8119537	2,219160351	11,03111405
37	0-90-90-0	0-90-90-0-CORE-0-90-90-0	8	0,153	4,776	6	0,0211752	0,229248	0,3986496	1,719755	10,01821139	2,219160351	12,23737174

Grafoam FPA-10

	Lay-up piatti esterni	Lay-up del cilindro	Numero ply	Spessore ply	Spessore CORE	Spessore totale del cilindro [mm]	m_A ply [g/cm2]	m_A core [g/cm2]	m_A cilindro [g/cm2]	Load Multiplier	Massa cilindro [kg]	Massa piatti [kg]	Massa totale [kg]
19	0-90-90-0	0-90-CORE-90-0	4	0,153	5,388	6	0,0211752	0,086208	0,1709088	1,070031	4,295001142	2,219160351	6,514161493
20	0-90-90-0	0-90-CORE-90-0	4	0,153	6,388	7	0,0211752	0,102208	0,1869088	1,416019	4,69708704	2,219160351	6,916247391
31	0-90-90-0	90-0-90-CORE-90-0-90	6	0,153	4,082	5	0,0211752	0,065312	0,1923632	1,300622	4,834158123	2,219160351	7,053318473
32	0-90-90-0	90-0-90-CORE-90-0-90	6	0,153	5,082	6	0,0211752	0,081312	0,2083632	1,706718	5,23624402	2,219160351	7,455404371
36	0-90-90-0	0-90-90-0-CORE-0-90-90-0	8	0,153	3,776	5	0,0211752	0,060416	0,2298176	1,321047	5,775401001	2,219160351	7,994561351
37	0-90-90-0	0-90-90-0-CORE-0-90-90-0	8	0,153	4,776	6	0,0211752	0,076416	0,2458176	1,782163	6,177486898	2,219160351	8,396647249

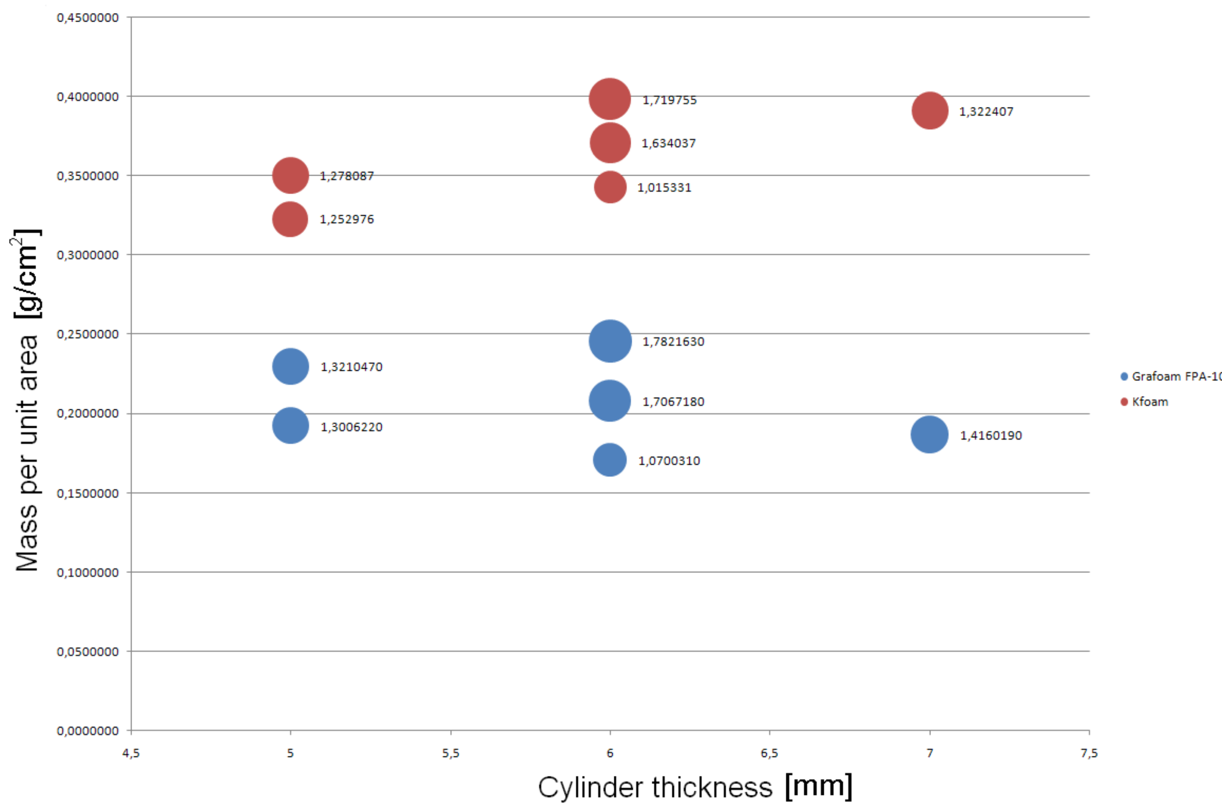
CYLINDER STRUCTURE



X-axis: cylinder thickness

Y-axis: mass per unit area

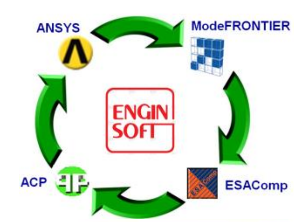
Bubbles area: Load Multiplier



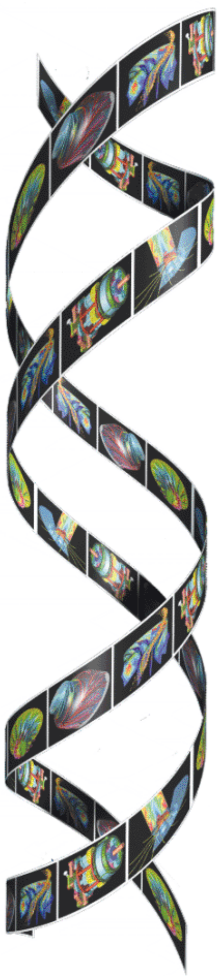
Anytime we could change the composite materials or the geometry of the model, obtaining in a short time the new results because our project is now completely …

Customized

Parameterized



EnginSoft – Company Informations



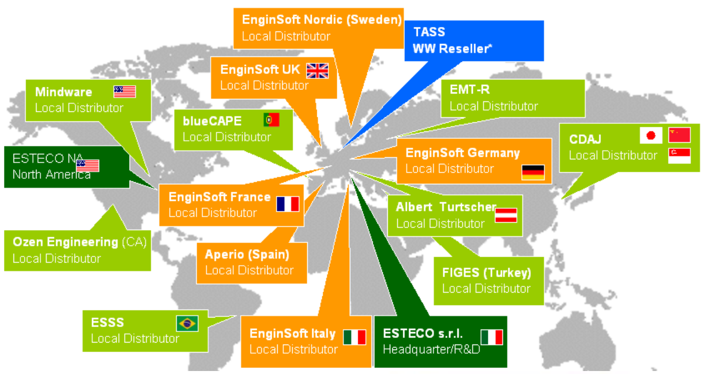
- STATUS: private company
- HISTORY: founded in 1984 but rooting back to 1973
- BASE AND BRANCHES: six main offices in Italy, Europe (Germany, France, UK, …), USA, Asia.
- NATURE OF BUSINESS:

  - Italy's leading Computer Aided Engineering software and services supplier.

  - Software sales, support, consultancy, education and training.

  - Participation in R&D project work (both EC and Italian research founded projects).

  - Research centre for numerical methods in engineering acknowledged by the Italian Ministry of University and Research.



Why EnginSoft?

Experience, development, multidisciplinary, knowledge, technology!

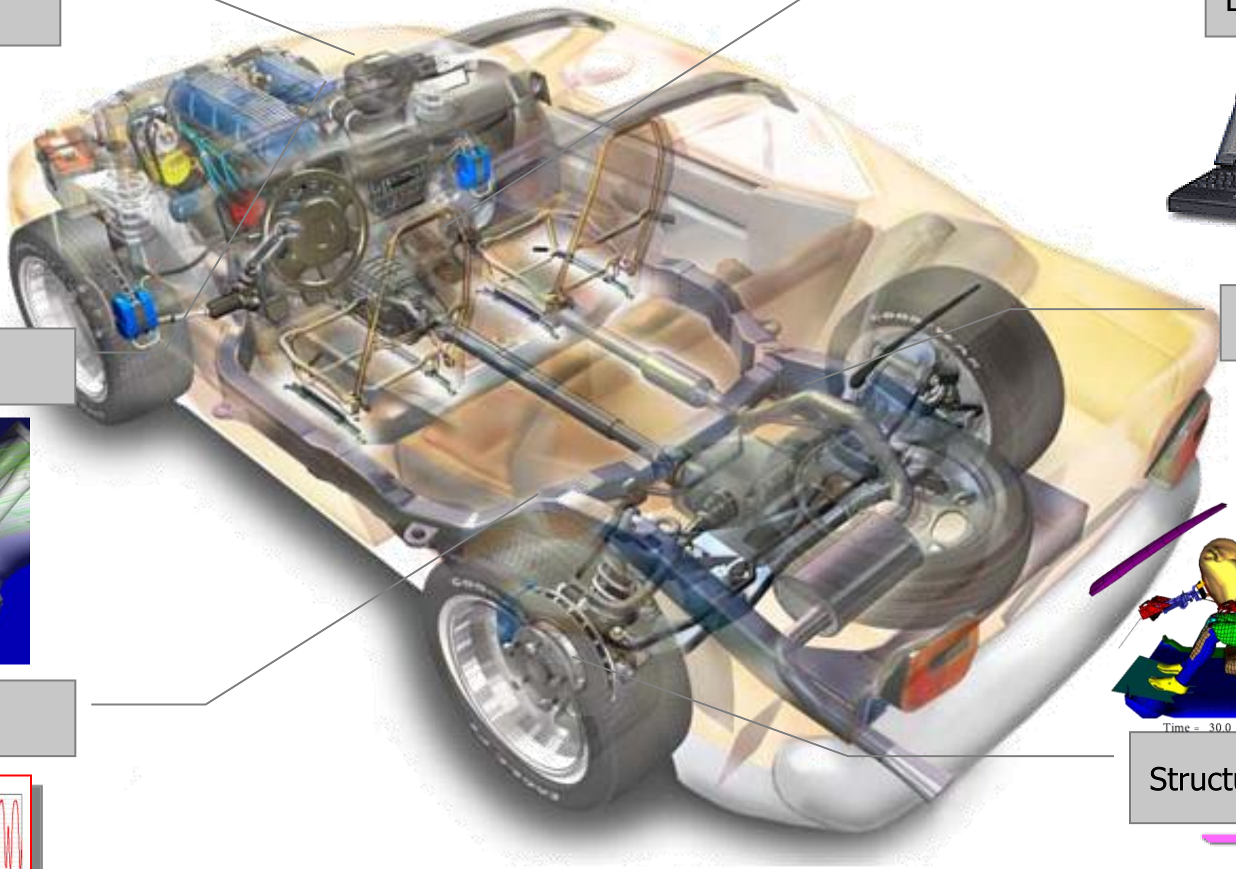
SIZE - MARKET

- Over 900 customers
- 100 technicians in the “direct” technical staff
- Over 1000 CAE application licences installed in Italy
- Constant growth during the past 6 years
- Own software applications (modeFRONTIER)
- Over 15 research projects in progress

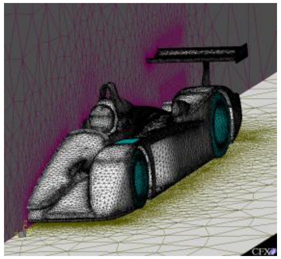
VIRTUAL PROTOTYPING

Controlling behaviors, performances and interactions of a product or component, that hasn’t been built yet, using computer models which, in real time, allow to test the response of any operating context and as regards any technical parameter.

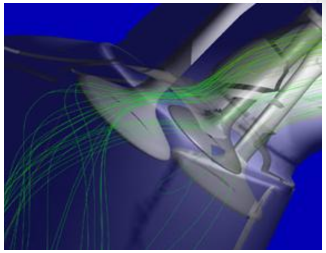
OVERVIEW OF APPLICATIONS



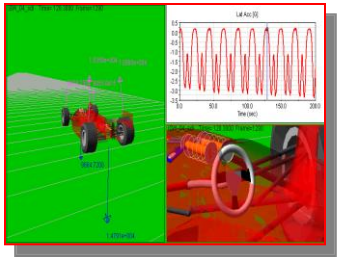
Car aerodynamics



Engine CFD

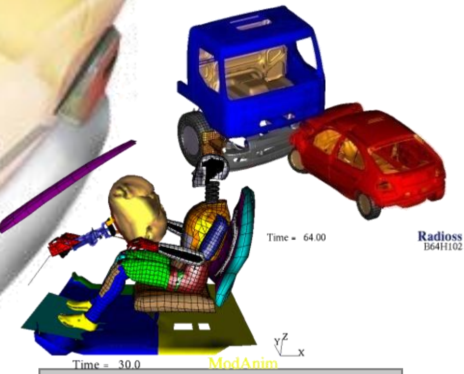


Car Dynamics



Electronics

Safety



Structural analysis

Partial list of customers worldwide

SULZER
NASA
Audi
HONDA
YAMAHA
National Eye Institute
QinetiQ
BAE SYSTEMS
TOYOTA
SUBARU
BR PETROBRAS
AIR LIQUIDE
EADS
DLR
Dasa-Rägister
Ford
BMW
TOKYO GAS
NIPPON OIL
ONERA
IVM Automotive
KOBELCO KOBE STEEL, LTD.
MBDA MISSILE SYSTEMS
AIRBUS
DAIMLERCHRYSLER
ISUZU
DENSO
IPA
SANDEN
GIAT industries
RAMGEN
NISSAN
mazda
MODINE
MARINTEK SINTEF GROUP
YKK
MITSUBISHI ELECTRIC PRESENTATION PRODUCTS
Matsushita Electric
HITACHI Inspire the Next
TOKYO ELECTRON
THOMSON
NIPPON SHARYO
SUMITOMO CHEMICAL
MICHELIN
Canon
TOSHIBA
Takeda
YOKOHAMA
BRIDGESTONE
MAHLE
FA & ROBOT FANUC

ENGIN SOFT

Partial list of customers in Italy

Merloni Elettrodomestici spa
BOSCH
TECHNIP KTI S.p.A.
IVECO
momo
JOHNSON GATE
FIAT
FiatFerroviaria
CIB UNIGAS
MAGNETI MARELLI
Electrolux
PIAGGIO
CANDY
SITGroup
aprilia
TDI
PIRELLI
NECCHI
BERCO
AGUSTA MV
IMMERGAS
GROVE
DRESSER
Teksid
speedline
BOLDROCCHI T.E. TECNOLOGIE CLIMATIZZATIVE
Campagnolo
Eni Snamprogetti
AGUSTA
EEMS
bticino
Ferrari
BEHR
PHILCO
ANSALDOBREDA
MARANGONI
MDC-DETROIT DIESEL ITALIA S.p.A.
GATE
VAMATEX
Avio
SIEMENS
FIAMM
DAB
SKF
EniChem
LUCCHINI
Whirlpool
Alenia AEROSPAZIO
DANA
DUCATI
NEW HOLLAND
PEDROLLO
Elkem
GHIAL
FINCANTIERI
Rockwell Automation
idreco
ENEA
CIRA
MOTOROLA
BRIDGESTONE

Thank you

for your attention

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